Appendix E

Plant List & Guidelines for Landscape-Based Stormwater Measures

Plant List & Guidelines for Landscape-Based Stormwater Measures

Introduction

Of the list of Best Management Practices published by the EPA, the following depend on plant material for their success:

- Infiltration Basin;
- Grassed Channel;
- Infiltration Trench;
- Vegetated Filter Strip;
- Dry Swale;
- Bioretention;
- Dry Detention Pond;
- Wet Swale;
- Wet Pond;
- Storm Water Wetland.

Therefore, the careful selection of plant species is a critical step in successful LID design and implementation. Plants facilitate natural infiltration of surface runoff, increase evapotranspiration, reduce the 'heat island' effect of urbanized areas, and reduce the rate, volume, and pollutant loading of urban runoff that ultimately ends up in local waterways or in local aquifers.

For the drainage features to function optimally, several plant characteristics need to be considered to determine their appropriateness for that particular BMP, and more specifically, the zone at which they are located within it. Most of these characteristics are included in the LID Plant List table, but basically for each plant selection, the following need to be looked at: water requirements; tolerance for inundation; root and leaf structure; and the ability to filter pollutants.

California native plants make up the entire LID Plant List, and this is the case for several reasons: they are perfectly adapted to local environmental conditions; they generally require less water and fertilization; and they limit the impact to native habitats. Native plants are also less susceptible to pests and diseases. There are a vast number of plants native to San Luis Obispo County that should provide designers with enough choices for virtually every scenario likely to be encountered. While the list does not include every suitable plant species for use within the County, it provides a good basis point for developing project specific plant palettes. Non-native species are inappropriate because they can become invasive, and water can quickly spread their occurrence and alter downstream habitats. Turf grass is also discouraged for LID drainage features due to its tendency to require large amounts of supplemental water, fertilizers, and regular maintenance.

The Planting Zones

Low Zone

The area at the bottom of the drainage feature where water temporarily ponds during either a rain event, or an upstream activity such as washing or irrigation. The low zone should not be designed to hold water, but should completely drain within 72 hours. However, during rainy seasons, this zone may be inundated for extended periods of time. Species planted in this zone should have the following characteristics:

- Water tolerant;
- Dense root structure and vegetative cover to discourage erosion, slow runoff velocities, and provide maximum pollutant filtration.
- Native grasses and groundcovers are excellent choices for this zone.

Mid Zone

The mid zone is the side slopes of the drainage feature, whose primary function is to slow down runoff velocity. While water passes through this area and saturates the soil, it does not stand for any period of time during typical storm events. Species planted in this zone should have the following characteristics:

- Tolerant of periodic inundation;
- Tolerant of periods without water;
- Dense root structure to provide erosion protection of side slopes.

High Zone

The top of the drainage feature will not see any standing water. Species planted in this zone should have the following characteristics:

- Deep roots to provide structural stability to the drainage feature;
- Tolerant of extended periods without water;
- Tolerant of occasional inundation.

Planting Design Criteria

There are numerous conditions to consider when choosing plant species for LID drainage features. Not surprisingly, many of the species on the LID Plant List have native habitats that mimic the various and (sometimes) disparate conditions that these features employ.

The purpose of the LID Plant List is to provide a cross section of suitable plant species as a base point for the development of project specific plant palettes. Designers and property owners are encouraged to propose other species that meet the spirit of these guidelines; the County will have the discretionary right to permit or deny their use. The following characteristics should be considered when proposing new plants:

- The planting zone(s) where the plant will be located (see Planting Zones Diagram); The size of the planting area and the size of the plant species at maturity;
  Native to California, preferably to San Luis Obispo County (non-native plants are inappropriate);
  Tolerant of San Luis Obispo County's climatic patterns (such as prolonged dry periods);
- Tolerant of seasonal flooding/inundation;
- Low maintenance requirements;
- Adaptability.

Plant species should aim to control erosion and wick water from soils. Some of the best choices for the low zone are groundcovers and grasses that quickly cover exposed soil. Low shrubs, grasses and groundcovers are suitable for the mid zone, depending on the area, gradient, soil type, and drainage patterns (sheet flow vs. concentrated flow, or flooding). Trees and larger shrubs are best planted in the high zone where their deeper roots can provide reinforcement to the drainage feature, and absorb the infiltration.

Energy dispersion devices may be required to be installed or constructed in certain situations to protect the integrity of the drainage feature, and the vegetation itself. These situations occur where features receive a concentrated flow, and may include such elements as gabions, weirs, or cobblestones. Where conditions absolutely demand, small areas of hardscape may be used.

Plant Layout

Some rules of thumb for planting layout of LID drainage features are:

- The smallest practical area of land should be exposed at any one time during development to minimize erosion. Erosion control measures should be integrated into planting designs, such as biodegradable erosion control mats. Plant mixes applied though a hydroseeding process should include erosion control specifications, which may be via a mulching process, or an integral part of the seed mix;
  Vegetation should be installed as soon as possible after soil is exposed;
  Plants should be laid out in staggered rows, and spaced so 100% coverage is attained at two-thirds of the species mature size.

Other Requirements

Soils Test

Prior to planting, but after grading operations are substantially complete, a soils test shall be undertaken by a qualified soil laboratory. The test results shall become a part of the design review submittal. Surface soils in San Luis Obispo County vary from almost pure sand at the coast, to heavy clay for much of the inland areas. Since the soils percolation rate, ability to allow the infiltration of water, and the depth to groundwater, is critical to the design of LID drainage features, this test will help to determine which BMP(s) are appropriate for that site. The soil report should contain, at a minimum:

- Native soil composition;
- Infiltration rates;
- Texture test;
- Depth at which groundwater was encountered (if at all);
- Cation exchange capacity;
- Agricultural suitability analysis;
- Recommended amendments for plant species to survive;
- Date of test.

Prior to planting, and on the advice of the soils report, the soil shall be amended to provide premium growing conditions for the plants specified.

Mulch

Immediately after planting, all exposed soil shall be covered with mulch to minimize erosion, and aid soil moisture retention. Mulch material may be either mineral (e.g. cobble or uncompacted decomposed granite) or biodegradable (e.g. bark or wood-chips). Biodegradable erosion control mats may also be used either on their own, or in conjunction with another mulch material. Mulch materials must not inhibit infiltration, and must be stable enough to withstand occasional high velocity runoff. Bark chips that have a tendency to float are not recommended. Acceptable mulching materials are:

- Nitrogen fortified bark (1" to 2" diameter);
- Redwood bark (1" to 2" diameter);
- Chipped gravel, crushed stone, or cobbles (1/2" to 2-1/2" diameter);
- 50/50 blend of top soil and aged compost.

Shredded bark (sometimes called 'Gorilla Hair') is not acceptable due to its tendency to form a tightly woven mat that can become almost impervious, and can also encourage mold growth.

Maintenance

Good design and planning can minimize the amount of maintenance required for a drainage feature. Weeds can be suppressed by a good coverage of vegetation, native plants require little, if any fertilizing and the avoidance of over-planting will reduce the amount of pruning needed. The most critical time for the vegetation is in the period immediately following construction, when plant species are not fully established; weed control, and supplemental irrigation may be required to ensure a healthy, vigorous vegetative cover.

It is worth noting the County policy of not using any herbicides or pesticides on any of their rights-of-way. Native plants are less susceptible to pests and diseases, and are therefore often more durable choices.

Given the nature of the LID drainage features, they will likely capture trash and debris (particularly after a significant rain event) and will need to be periodically cleaned out. Depending on the adjacent land uses, there may also be a build-up of silt that should be removed as necessary to allow optimum functionality of the feature. In the event that cleaning and maintenance operations damage the vegetation, it should be replaced as soon as possible.

Nursery Sources

Environmental Seed Producers Inc.
P.O. Box 2709
Lompoc, CA 93438
(805) 735-8888
www.espseeds.com

Las Pilitas Nursery
3232 Las Pilitas Road
Santa Margarita, CA 93453
(805) 438-5992
www.laspilitas.com

Native Sons Inc.
379 West El Campo Road Arroyo Grande, CA 93420 (805) 481-5996
www.nativeson.com

S&S Seeds
P.O. Box 1275
Carpinteria, CA 93014
(805) 684-0436
www.ssseeds.com

San Marcos Growers
125 South San Marcos Road Santa Barbara, CA 93111
(805) 683-1561
www.smgrowers.com

slo starts
1858 Los Osos Valley Road Los Osos, CA 93402
(805) 528-7533

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Joni L. Janecki & Associates, Inc. City of Salinas Development Standards Plan - LID Development Practices for Urban Storm Drainage Management, 2007.

Bornstein, Fross & O'Brien. California Native Plants for the Garden. Cachuma Press, Los Olivos, California, 2005

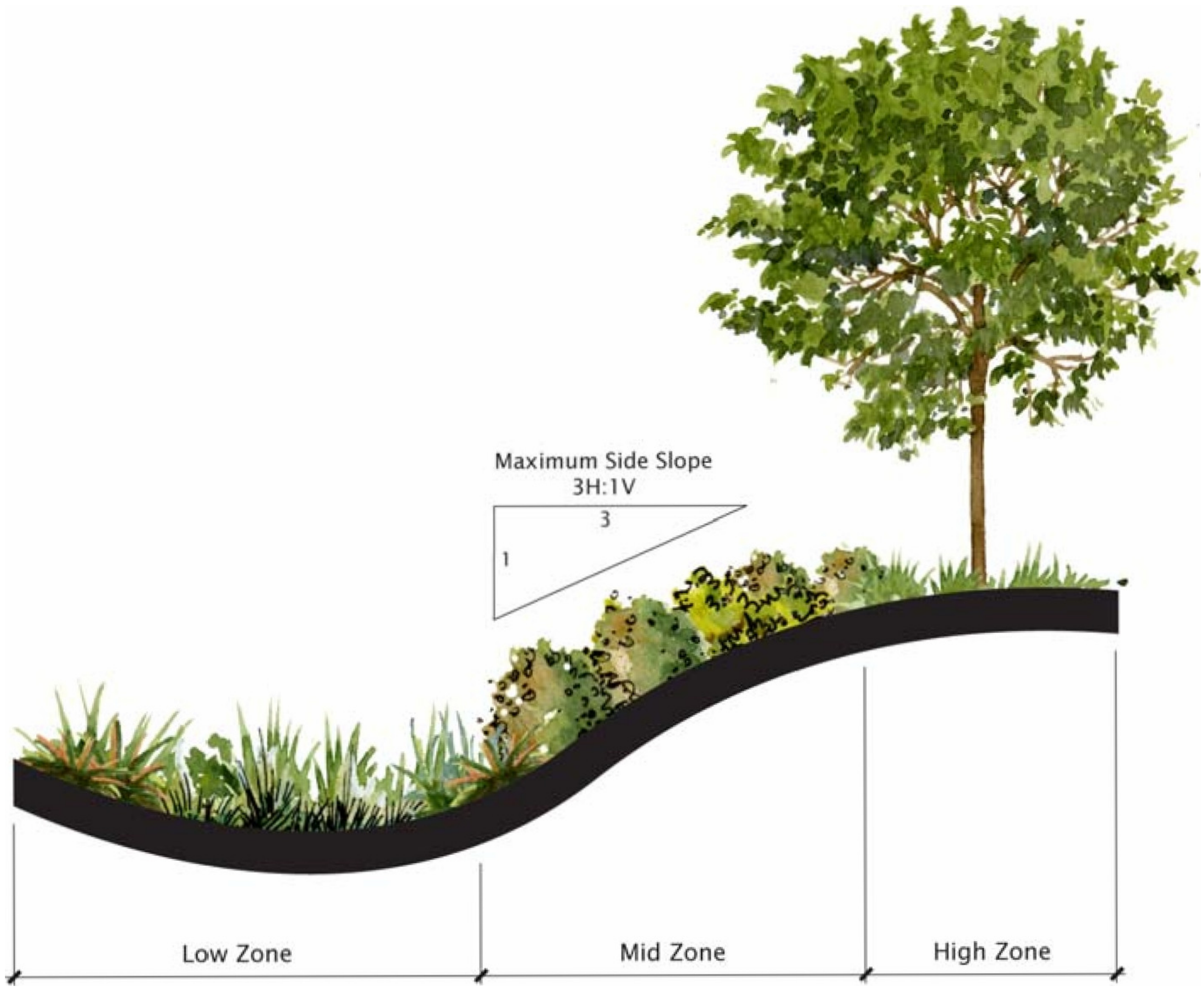
Greenlee, John. The Encyclopedia of Ornamental Grasses. Rodale Press, Pennsylvania, 1992

Las Pilitas Nursery. Online native plants information resource. Available at www.lasoilitas.com.

Native Sons Nursery. Online native plants information resource. Available at www.nativeson. com.

USDA Natural Resources Conservation Service Plants Database. Online plant information resource. Available at htto://olants.usda.gov/

US Environment Protection Agency. Online storm water BMP resource. Available at v.nv.emcw.



Planting Zones Diagram

This diagram illustrates the three basic planting zones for landscape-based stormwater measures. Used in conjunction with the LID Plant List, it shows the general zones that are recommended for each species. Site specific conditions should also be considered, such as solar orientation and micro-climate.

Plant List for Landscape-Based Stormwater Measures

Botanical Name	Common Name[3]	Planting Zones[1]			LID Design Considerations[2]									Notes
		Low Zone	Mid Zone	High Zone	Small Planting Strips (< 5' Wide)	Large Planting Areas (> 5' Wide)	Tolerates Prolonged Saturation	Tolerates Periodic Flooding	Tolerates Prolonged Dry Periods	Requires Good Drainage	Tolerates Mowing	Phytoremediation Capabilities	Tolerates Clay Soils	
GRASSES, GROUNDCOVERS, FERNS & BULBS														
Achillea millefolium	Yarrow		✓	✓	✓	✓				✓	✓		✓	Good erosion control
Aguilegia formosa	Western Columbine	✓			✓	✓	✓	✓	✓					
Arctostaphylos app.	Manzanita		✓	✓	✓	✓			✓	✓				
Bothriochloa barbinodis	Cane Bluestem		✓	✓	✓	✓		✓	✓	✓				Good erosion control
Bromus carinatus	California Brome		✓	✓	✓				✓					
Calamagrostis nutkaensis	Pacific Reedgrass		✓		✓	✓		✓	✓					
Calochortus albus	White Fairy Lantern		✓		✓	✓		✓	✓					
Carex pansa	California Meadow Sedge	✓	✓		✓	✓		✓		✓				Good erosion control
Carex praegracilis	Dune Sedge	✓	✓		✓	✓		✓	✓	✓	✓			Good erosion control
Carex tumulicola	Foothill Sedge	✓	✓	✓	✓	✓	✓	✓	✓		✓			Good erosion control
Castilleja miniata	Indian Paintbrush		✓	✓	✓	✓			✓	✓				
Deschampsia caespitosa	Tufted Hair Grass		✓		✓	✓		✓	✓	✓				Needs irrigation
Deschampsia holciformis	Pacific Hair grass	✓	✓		✓	✓	✓	✓						

Botanical Name	Common Name[3]	Planting Zones[1]			LID Design Considerations[2]									Notes
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Dadleya puiverulenta	Chalk Dudleya		✓	✓	✓	✓			✓	✓				Not in north County/ California Valley
Eleotharis macrostachya	Common Spike Rush	✓	✓		✓	✓	✓	✓						
Eschscholcia californica	California Poppy		✓	✓	✓	✓			✓	✓				
Festuca californica	California Fescue		✓	✓	✓	✓		✓	✓					Good erosion control
Festuca idahoensis	Western Fescue	✓	✓	✓	✓	✓		✓	✓					Good erosion control
Fragaria chiloensis	Beach Strawberry		✓		✓			✓	✓	✓				
Helichera micrantha	Crevice Alum Root		✓	✓	✓	✓		✓	✓	✓				
Hordeum californicum	California Barley		✓	✓	✓	✓		✓	✓	✓			✓	
Hordeum intercedens	Bobtail Barley		✓	✓	✓	✓		✓	✓	✓			✓	
Iris douglasiana	Douglas Iris		✓	✓	✓	✓		✓		✓				Good erosion control
Juncusacutus	Spiny Rush	✓	✓		✓	✓	✓	✓	✓					Good erosion control
Pincus bufonius	Toad Rush	✓	✓		✓	✓	✓	✓	✓					Good erosion control
Juncus effusus	Soft Rush	✓	✓		✓	✓	✓	✓	✓					Good erosion control
Juncus mexicanus	Mexican Rush	✓	✓		✓	✓	✓	✓	✓					Good erosion control
Juncus patens	Wire Grass	✓	✓		✓	✓	✓	✓	✓					Good erosion control

Botanical Name	Common Name[3]	Planting Zones[1]			LID Design Considerations[2]									Notes
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Lasthenia californica	California Goldfields	✓	✓		✓	✓	✓	✓	✓				✓	
Lasthenia glabrata	Yellowray Goldfields	✓	✓		✓	✓	✓	✓	✓				✓	
Layia platyglossa	Tidy Tips		✓	✓	✓	✓			✓					
Leymus condensatus	'Canyon Prince' Canyon Prince Wild Rye		✓	✓					✓					
Leyrnus triticoides	Creeping Wild Rye	✓	✓		✓	✓		✓	✓		✓		✓	Fast spreading
Lilium pardalinum	Leopard Lily		✓			✓		✓	✓	✓				
Linanthus parvi florus	Stardust		✓	✓	✓	✓			✓	✓				Annual
Lupinus microcarpus var. densiflorus	Whorled Lupine		✓	✓	✓	✓			✓	✓				Annual
Melica imperfecta	Coast Melic Grass		✓	✓	✓			✓						Not directly on coast
Muhlenbergia rigens	Deer Grass		✓	✓	✓	✓		✓	✓				✓	Good erosion control; Fast spreading
Nassella pulchra	Purple Needlegrass		✓	✓		✓			✓		✓			State grass of California
Polystichum muniturn	Sword Fern		✓		✓	✓		✓						
Salvia app.	Sage		✓	✓	✓	✓		✓	✓					Not directly on coast; Fast growing

		Planting Zones[1]			LID Design Considerations[2]									
Botanical Name	Common Name[3]	Low Zone	Mid Zone	High Zone	Small Planting Strips (< 5' Wide)	Large Planting Areas (> 5' Wide)	Tolerates Prolonged Saturation	Tolerates Periodic Flooding	Tolerates Prolonged Dry Periods	Requires Good Drainage	Tolerates Mowing	Phytoremediation Capabilities	Tolerates Clay Soils	Notes
Satureja douglasii	Yerba Buena	✓	✓		✓			✓					✓	
Scirpus californicus	California Bulrush	✓				✓	✓	✓						
Scirpus maritimus	Saltmarsh Bulrush	✓				✓	✓	✓						
Sisyrinchium helium	Blue-Eyed Grass		✓	✓	✓	✓			✓		✓			
Symphoricarpus monis	Creeping Snowberry		✓	✓		✓			✓					Good erosion control
Triteleia laza	Ithuriel's Spear		✓	✓	✓	✓		✓	✓					
VINES														
Clematis lasiantha	Chaparral Clematis		✓	✓		✓			✓	✓				
Vitis californica	California Wild Grape	✓	✓	✓	✓	✓		✓	✓	✓				
SHRUBS														
Arctostaphylos app.	Manzanita		✓	✓	✓	✓			✓	✓				Good erosion control
Baccharis pilularis	Coyote Brush			✓	✓	✓		✓	✓					Good erosion control; Fast growing
Baccharis salicifolia	Mulefat		✓	✓		✓	✓	✓	✓					
Barbaric aguifolium	Oregon Grape			✓	✓	✓			✓					

Botanical Name	Common Name[3]	Planting Zones[1]			LID Design Considerations[2]									Notes
		Low Zone	Mid Zone	High Zone	Small Planting Strips (< 5' Wide)	Large Planting Areas (> 5' Wide)	Tolerates Prolonged Saturation	Tolerates Periodic Flooding	Tolerates Prolonged Dry Periods	Requires Good Drainage	Tolerates Mowing	Phytoremediation Capabilities	Tolerates Clay Soils	
Ceanothusspp.	Wild Lilac			✓		✓				✓				Good erosion control; Fast growing
Cornus sericea	Creek Dogwood	✓	✓	✓	✓	✓	✓	✓					✓	Good erosion control; Allergenic
Fremontodendron californica	Flannel Bush			✓		✓				✓				Fast growing
Garrya elliptica	Coast Silk-Tassel			✓	✓	✓			✓	✓			✓	
Heteromeles arburifolia	Toyon			✓		✓			✓	✓				Good erosion control
Lupimis albifrons	Silver Bush Lupine		✓	✓		✓			✓	✓				Fast growing
Myrica californica	Pacific W. Myrtle		✓	✓		✓		✓						Fast growing
Rhainnus californica	Coffeeberry		✓	✓		✓		✓	✓					Good erosion control
Ribes sanguineurn	Pink-Flowering Currant		✓	✓	✓	✓	✓	✓	✓				✓	Good erosion control
Ribes speciosum	Fuchsia-Flowering Gooseberry		✓		✓		✓	✓					✓	Good erosion control
Ribes viburnifolium	Catalina Perfume		✓	✓	✓	✓	✓	✓	✓				✓	Good erosion control
Rosa californica	California Wild Rose		✓	✓		✓	✓	✓	✓					Good erosion control; Potentially invasive
Babas ursinus	California Blackberry		✓			✓		✓	✓				✓	

Botanical Name	Common Name[3]	Planting Zones[1]			LID Design Considerations[2]									Notes
		Low Zone	Mid Zone	High Zone	Small Planting Strips (< 5' Wide)	Large Planting Areas (> 5' Wide)	Tolerates Prolonged Saturation	Tolerates Periodic Flooding	Tolerates Prolonged Dry Periods	Requires Good Drainage	Tolerates Mowing	Phytoremediation Capabilities	Tolerates Clay Soils	
Sambucus mexicana	Elderberry		✓	✓	✓	✓	✓	✓	✓				✓	Good erosion control; Fast growing
TREES														
Acer tnacrophyllum	Big-Leaf Maple		✓	✓		✓	✓	✓						Fast growing
Aesculus californica	Buckeye			✓		✓	✓	✓	✓				✓	Good erosion control
Alnus rhombi folio	White Alder		✓	✓		✓	✓	✓						Fast growing
Cercis occidentalis	Western Redbud		✓	✓	✓	✓		✓	✓	✓				Good erosion control
Platanus racemosa	California Sycamore		✓	✓		✓		✓						Fast growing
Papules fremontii	Western Cottonwood		✓	✓		✓	✓					✓		Good erosion control; Fast growing
Prunus ilicifolia sap. Lyonii	Catalina Cherry			✓	✓	✓	✓	✓	✓				✓	
Salix laevigata	Red Willow	✓	✓	✓	✓	✓	✓	✓				✓		
Salix lasiolepis	Arroyo Willow	✓	✓	✓	✓	✓	✓	✓				✓		
Umbellularia californica	California Bay Laurel			✓		✓	✓	✓						

Footnotes:

[1] See Planting Zone illustration above for zones as they relate to stormwater BMP's.

[2] Lid design considerations are specific factors that relate to landscape-based stormwater measures. Designers should also consider usual environmental factors such as sun/shade requirements, coastal exposure, wind tolerance, etc., when developing site specific plant lists.

[3] All plant species are considered native to California to limit impact to native habitats, and take advantage of their natural suitability to San Luis Obispo County's climate. All are considered appropriate for use throughout the entire county unless noted otherwise.

Appendix F

Additional Resources

PART 1 – RETENTION GRADING STEPS

Infiltration practices work best in residential, commercial and industrial areas with NRCS type A and B hydrologic group soils. Retention grading earthworks that are distributed and sized to retain the tributary are to it wile not exceeding a berm height shown in the table below are except from completing infiltration testing specified further in this section and will not require underdrains, event in NRCS type C and D hydrologic group soils.

Bioretention projects located in NRCS type C and D hydrologic group soils may require an underdrain. Project that require an underdrain do not need to test the sites inherent infiltration rate. The NRCS soil web survey is available on-line at http://websoilsurvey.nrcs.usda.gov/

Regardless of which practice is used, infiltration practices should not occur in areas where:

- known geologic instability exists that would be exacerbated by increased infiltration
- where contaminates are present in the soil or aquifer below the site
- in areas with high bedrock elevations
- within 10 ft away from structure foundation unless structure foundation is protected from water damage
- high groundwater in the area may create additional problems
- on steep banks or in highly erodible soils
- over septic fields or leach lines

Infiltration rates are dependent on rainfall intensity, receiving ground slope and permeability of soils and subsoil(s), soil structure, surface vegetation, soil moisture and soil biota. To determine if a site is well suited for infiltration BMPs, the following four step process is provided.

Step 1. Initial Screening.

Eliminate areas within site with
- Existing topography and slopes greater than 20%
- Groundwater and bedrock depths shallower than 10 feet

Eliminate areas located within
- 500-ft of an area of known groundwater contamination or underground fuel tank
- FEMA defined 100-year flood plain
- 250 feet of public wells
- 100 feet of private wells and riparian corridors (Schueler,1987)
- 50 ft of septic system or leach field
- 100 ft of roadways with average daily traffic of 25,000 trips or greater for main road
- 100 ft of intersecting roadway with average daily traffic of 15,000 trips or greater

Highlight remaining areas with NRCS hydrologic soil group type A or B

To complete step 1, a to-scale site plan/map, including topography, of the entire development site plus 500-feet beyond site boundary is prepared. This map is intended to aid the development team in determining areas potentially suitable for infiltration BMPs and should also incorporate relevant information (i.e. tree conservation and archeological areas, etc) identified when the constraints map was developed (See Section 4.2.1).

Infiltration BMPs must be at a lower elevation than the adjacent areas from which they will receive runoff.

Projects located in NRCS hydrologic soil group type C and D soils are less suitable for infiltration BMPs because the soils do not allow significant volumes of runoff to infiltrate them. Projects with these slow draining soils must utilize a permeable backfill in conjunction with an underdrain or alternative BMPs such as vegetated swales and strips. As a result, these projects can skip step 2 and proceed to field testing of the proposed BMP location as specified in step 3.

Step 2.	Characterize soil (structure, USDA texture, gradation, percent fines, and soil horizons) at the proposed bottom and 4-ft below the bottom of the proposed BMP. One sample must be evaluated by a licensed geotechnical engineer for each considered location, regardless of type or size.

The soil horizon information is used to identify the relative infiltration rates based on each horizon (see Table 6.3).

Table 6.3: Design Infiltration Rates for Soil Textures Receiving Stormwater

SOIL TEXTURE	INITIAL INFILTRATION RATE (IN/HR)
Coarse sand or coarser, loamy coarse sand, sand	3.600
Loamy sand	1.630
Sandy loam, fine sand, loamy fine sand, very fine sand and loamy fine sand	0.500
Loam	0.240
Silt loam	0.130
Sandy clay loam	0.110
Clay loam	0.030
Silty Clay loam	0.043
Sandy clay	0.040
Silty clay, clay	0.070

The infiltration rate of the soil texture with the least permeable soil can be used an as initial indicator of the sites infiltration rate. Infiltration rates less than 0.5-inches per hour (indirect infiltration) and 1.0-inches per hour (direct infiltration) do not drain quickly enough for use as an infiltration system without the addition of an underdrain. Infiltration rates that exceed 3-in/hr (indirect or direct) are considered at risk of introducing contaminants into groundwater supplies and should only be used where it can be demonstrated that pre-treatment of the runoff will confidently eliminate that risk. These sites will also require significant irrigation to sustain surface landscaping.

The number of potential infiltration testing locations can be reduced by the elimination of all evaluated areas that have percent fines greater than 10 percent. Sites with excessive percent fines tend to clog the pore spaces in the soil, thereby reducing its ability to function as designed.

Distributing small infiltration areas throughout the site is preferred over the use of large retention basins. Depending on the site, using a combination of small, natural stormwater retention areas can reduce the overall size of a flood control detention and piping system.

Step 3.	Determine types of suitable infiltration BMPs for the location

Remaining potential infiltration sites can be preliminarily sized based on the estimated infiltration rate for the textural class identified in the samples evaluated. There are many types of infiltrating BMPS including bioretention systems, swales, retention basins, dry wells, infiltration trenches, modular pavements and rain gardens. Often site conditions point towards one BMP being more appropriate than another.

Upon completion of step 3, the anticipated footprint and its location relative to proposed structures should be included on the infiltration feasibility map. Most infiltration BMPs will require a 10-ft setback downslope of a structure, unless the structure is protected with a water/vapor barrier (Stego wrap, Mirafi 570, etc). The liner should be uv-stabilized to assure long lasting protection. A hundred (100 ft) setback should be maintained upslope from building foundations.

Each infiltration area requires an overland escape path. Having a series of smaller infiltration areas can reduce the risk of failure that is typically associated with a single site solution and has been found to reduce the water quality treatment needed at "end of pipe" locations.

Step 4.	Establish Design Criteria for Infiltration BMPs

The evaluation requirements are specific to the infiltration device being proposed. Table 6.4 provides a list of testing requirements for each type of infiltration BMP currently accepted by the County.

a. Vertical separation distance should be based on highest anticipated seasonal groundwater elevation with consideration of the potential increase in the maximum height of the water table due to the infiltration device. Groundwater mounding calculations by a geotechnical engineer shall be conducted in areas where slope stability is a concern and/or at locations with a high water table.

b. Specific infiltration rates used in design shall be in accordance with **one** of the following:
   i. The last field measured percolation rate, as adjusted by standard correction factors, for a 12x12x12 or a 4, 6 or 8-inch bore hole extending five feet below

the bottom of the proposed elevation of the infiltration system and based on an average of two **falling head percolation tests** with a minimum four hour soaking period. (A constant head percolation test can be used for test holes that can't maintain a pre-soak condition).

Testing frequency should be consistent with the testing frequency provided in Table 6.5. The design infiltration rate is the average of the individual test holes of each infiltration facility.

Table F-1: Design Infiltration Rates Test frequency Requirements

<table>
<tr><th>INFILTRATION BMP</th><th>TEST REQUIRED</th><th>MIN. NO. OF TESTS REQUIRED*</th></tr>
<tr><td>Rain Gardens</td><td rowspan="5">Pits or borings (5-feet or depth to limiting layer, whichever is less).</td><td>N/A</td></tr>
<tr><td>Infiltration Trench (≤ 2000 sf of contributing drainage area)</td><td>1 test/100 linear feet of trench with a minimum of 2, and sufficient to determine variability.</td></tr>
<tr><td>Infiltration Trench (> 2000 sf of contributing drainage area)</td><td rowspan="2">1 test/50 linear feet of trench with a minimum of 2, and sufficient to determine variability.</td></tr>
<tr><td>Bioretetion systems</td></tr>
<tr><td>Infiltration Grassed Swales</td><td>1 test/1000 linear feet of trench with a minimum of 2, and sufficient to determine variability.</td></tr>
<tr><td>Retention Basins</td><td rowspan="2">Pits to 10-feet or depth to limiting layer. Borings to 20 feet or depth to limiting layer. Include mounding potential.</td><td rowspan="2">2 pits required per infiltration area with an additional 1 pit or boring for every 10,000 sf of infiltration area and sufficient to determine variability</td></tr>
<tr><td>Dry Wells</td></tr>
</table>

**The depth and number of test holes, pits and samples should be increased if, in the judgment of a licensed geotechnical engineer, the conditions are highly variable and such increases are necessary to accurately estimate the performance of the system.*

ii. One third of the field measured infiltration rate for soils five feet below the bottom of the proposed elevation of the infiltration system based on **double-ring infiltrometer** requirement of ASTM D3385.

iii. Single family residences may use an adjusted infiltration rate based on a ratio of the initial infiltration rate associated with the samples **soil texture** and a factor of safety of 0.8. The initial design infiltration rate value is based on the soil texture of the least permeable soil below the bottom elevation of the infiltration device (see Table 6.3).

The adjusted infiltration rate used in subsequent design calculations requires the initial infiltration rate be multiplied by 0.8. The 0.8 represents a safety factor to account for potential clogging, bio-buildup and site variability.

Example.
Sand (3.6 initial infiltration rate) x 0.8 (safety factor) = 2.88 (adjusted infiltration rate)

Step 5 and 6.	Test material proposed for back fill, verify system performance Material proposed for back fill may consist of excavated material, imported material or a combination of the two and shall be subject to a textural analysis to verify it conforms to current bioretention media properties.

The last steps are included in this section for continuity and are not associated with determining if a particular site is well suited for infiltration BMPs. Step 5 is intended to verify that the material used as backfill meets the design criteria. This step should be included prior to construction. Areas designated for infiltration BMPs should be protected from construction equipment and from receiving sediment-laden construction site runoff.

Step 6 is intended to verify the system is performing as designed. It is required at the option of the county and is uses the percolation rate procedures identified in step 4.

Soils in catchment ponding areas should not be compacted. Spillways or channels can be used to link and distribute water throughout the site. Grass filter strips are excellent at pre-treating sediment laden runoff.

Shallow depressions must drain within 72 hours. See Chapter **6** for information on determining infiltration rates and tips for increasing infiltration rates.

Hydrograph Analysis

Projects shall strive to infiltrate a specific depth of rainfall from each storm based upon a hydrograph analysis using the annual average rainfall as follows:

Table F-2. Depth of Storm to Be Retained On-Site

AVERAGE ANNUAL RAINFALL	DEPTH OF RAINFALL TO BE TREATED PER ACRE
Less than or equal to 15 inches	0.50-inches
15 and less than or equal to 18 inches	0.75-inches
18 and less than or equal to 25 inches	1.00-inches
Greater than or equal to 25 inches	1.32-inches

A hydrograph analysis allows an evaluation of the relationship between runoff and rainfall over an isolated storm event. There are several commercial software packages available for use in analyzing hydrographs. Regardless of which package is used, the software should be set up as follows:

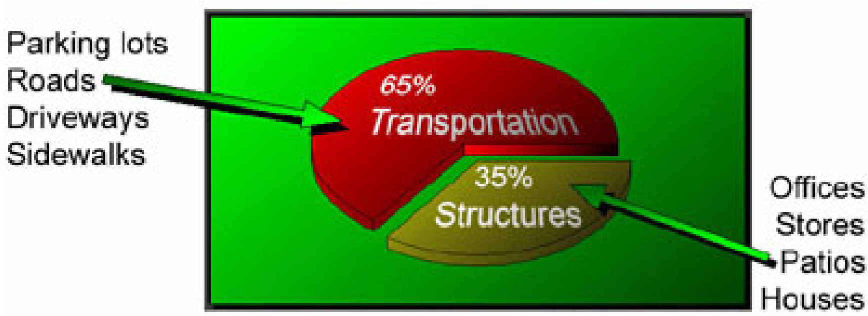
Hydrograph Method:	SBUH or custom localized curve, if available*
Time Interval:	1 minute
Storm Distribution/Duration:	Type I, 24-hours

Rainfall Depths:	See table above
Antecedent Moisture Condition:	AMC II
Time of Concentration:	Per TR-55 Manual

PART 2 – REDUCING IMPERVIOUS SURFACES

Reducing Impervious Surfaces

Materials that prevent or substantially reduce infiltration of water into the soil are considered impervious surfaces. Examples of common impervious surfaces associated with development include roof tops, roads, parking lots, sidewalks and driveways. Studies have shown that the majority of impervious surfaces are a result of transportation infrastructure.



Source: Nemo, based on City of Olympia ISRS Final Report

Impervious areas significantly contribute to the amount of contaminates typically found during "first flush" stormwater events.

Strategies employed to reduce impervious surfaces include:

1. Concentrating buildings on soils that are inherently less suitable for infiltration, rather than on site soils characterized with a greater infiltration rate.(See 4.2.1)
2. Clustering structures. (See 4.2.3)
3. Minimizing area dedicated to parking lots and driveways. (See Section 4.2.4)
4. Specifying the narrowest road length and width to meet (but not exceed) the needs of the development (pedestrian, cyclists and motorist safety, traffic volumes). (See Section 4.3.1)
5. Utilizing pervious materials able to fulfill the same function of impervious materials. (See Section 4.3.5)

Understanding the difference between the pre- and post-project impervious area can provide insight into the likely hydromodification effects resulting from the project.

<u>Measuring the Imperviousness of a Site</u>

Rational Coefficients are typically used in the Rational Formula to estimate peak runoff rates. The dimensionless Rational Coefficient can be used as a means to compare the relative absorptive nature that exists between various types of materials.

Runoff Coefficients values range between 0.0 and 1.0 where a value of 0.0 indicates that none of the rain falling on the surface will generate runoff. Conversely, a value of 1.0 indicates that all of the rain falling on the watershed will be carried offsite as runoff.

Typically, one value is selected for the site (i.e. single family residential on 1- acre lots). This approach does not encourage the use of pervious materials nor does it encourage development to take place on the most impervious soils of the site. As some soils (i.e. sand) are better able to absorb runoff than other soils (i.e. clays), purposely constructing new impervious surfaces on less impervious soils will maximize the preservation of remaining soils with higher capacity to infiltrate. The relative advantage of building on one soil type over another is negligible on site with fairly homogenous soil types. For large development tracts with contrasting soil types, however, the advantage of conserving the soils that contribute greatest to groundwater recharge could be significant.

A different method of determining pre- and post-development project rational coefficients is necessary to promote conservation of the most pervious areas and development on the areas already prone to produce runoff. This method calculates composite Rational Coefficients based on an analysis of the site in discrete units (driveways, roads, roofs, lawn and natural vegetation area) instead of larger categories.

Additionally, since some materials are able to absorb surface runoff rather than shed it, replacing impervious materials with materials that are able to serve the same function as intended and reduce the amount of runoff leaving the site. Examples of material substitutions commonly used to replace asphalt and concrete surfaces include porous concrete, vegetated pavers, wood decking or gravel.

Table 6.1 provides relative Runoff Coefficients for several materials commonly used in development projects. Where a reasonable range of runoff coefficient values is given, the actual value of runoff coefficient may vary based on the antecedent moisture condition of the soil, the type of soil, and slope of the project. Where vegetation or pervious materials are specified, an evaluation of the corresponding hydrologic soils group (HSG), as defined by the Natural Resources Conservation Service (NRCS), and the pervious material must be made to determine if the underlying soil or the pervious material is the limiting factor.

Table F-3. Rational Coefficient Table

<table>
<tr><th rowspan="2">Surface Type</th><th colspan="4">Hydrologic Soil Group</th><th rowspan="2">Source</th></tr>
<tr><th>A</th><th>B</th><th>C</th><th>D</th></tr>
<tr><td>Pools, ponds, creeks and streams</td><td colspan="4">1.00</td><td>3</td></tr>
<tr><td>Portland Concrete Cement, Asphalt Concrete & Roof, Conventional</td><td colspan="4">0.95</td><td>1, 2</td></tr>
<tr><td>Brick (grouted)</td><td colspan="4">0.85</td><td>3</td></tr>
<tr><td>Pervious Concrete/Asphalt (>6”), for < 6-inches, use runoff coefficient of the subgrade</td><td colspan="4">0.05 or design rainfall intensity(in/hr) – 4.0 (in/hr)</td><td>3</td></tr>
<tr><td>Vegetated Pavers with established vegetation</td><td>0.25</td><td></td><td></td><td>0.40</td><td>5</td></tr>
<tr><td>Unit Pavers, use runoff coefficient of the subgrade if pavers are laid over an aggregate base with more than 15% void content</td><td colspan="4">0.10</td><td></td></tr>
<tr><td>Wood Decking</td><td colspan="4">use subgrade runoff coefficient</td><td></td></tr>
<tr><td>Cobbles</td><td></td><td></td><td></td><td>0.6</td><td>3</td></tr>
<tr><td>Gravel</td><td>0.30</td><td>0.45</td><td>0.50</td><td>0.50</td><td>4</td></tr>
<tr><td>Roof, Garden Roof (<4 in)</td><td colspan="4">0.50</td><td>2</td></tr>
<tr><td>Roof, Garden Roof (4 – 8 in)</td><td colspan="4">0.30</td><td>2</td></tr>
<tr><td>Roof, Garden Roof (8.01 - 20 in)</td><td colspan="4">0.20</td><td>2</td></tr>
<tr><td>Roof, Garden Roof (> 20 in)</td><td colspan="4">0.10</td><td>2</td></tr>
<tr><td>Lawns (0 < slope < 2 %)</td><td>0.05</td><td>0.10</td><td>0.13</td><td>0.17</td><td>CERM</td></tr>
</table>

Lawns (2 < slope < 7 %)	0.10	0.15	0.18	0.22	CERM
Lawns (slope > 7 %)	0.15	0.20	0.25	0.35	CERM
Unimproved	Use SLO County Standard Plan H-3a "Runoff Coefficients for Undeveloped Areas"				

1 Bay Area Stormwater Management Agencies Association 2 State of Minnesota Sustainable Building Guidelines
3 Menlo Park 4. Iowa Stormwater Management Handbook
CERM Civil Engineering Reference Handbook, Lindberg
5 Smith, D.R., "Evaluations of Concrete Pavements in the United States," in Proceedings of the Second International Conference on Concrete Block Paving, University of Delft, the Netherlands, April 1984, pp. 330-336 and Ferguson, B.K., Porous Pavements, CRC Press Boca Raton, Florida, 2005, p. 126.

Runoff coefficients used in calculations should be taken from Table 6-1. Coefficients that deviate from those above can be used if documented to the satisfaction of the Department of Public Works. A sample calculation for determining weighted Rational Coefficients is provided below.

Source: studio0202.files.wordpress.com

Table F-4. Comparison of Runoff Coefficients for Various Conventional and LID Scenarios Illustrating Revised Rational Coefficient Example Calculations

SCENARIO	RUNOFF COEFFICIENT	SURFACE TYPE DESCRIPTION
Pre-developed	0.31	Using SLO County Standard Plan H-3a with low relief, normal soil infiltration, excellent vegetal cover, normal surface storage.
Traditional	0.40	Residential lots 10,000 sf to 19,999 sf, 2-10%, Sand soil (per SLO County Standard Plan H-3)

Revised (Initial)	0.55	All impervious and paved areas (roof, asphalt, concrete, decking and pool) have a 0.95 rational coefficient, all vegetated areas have a 0.15 rational coefficient for lawns greater than 2% but less than 10% on Hydrologic Soil Group B.
Revised (Improved, run 1)	0.37	Replaced sidewalk with pervious concrete, uses unit pavers for driveway and pool deck area. Wood decking used underlying soil rational coefficient.
Revised (Improved, run 2)	0.27	Same scenario as Improved, run 1 but with the addition of a 4-inch green roof.

The traditional and revised approach (initial) should be comparable with each other, but in the above example, the current approach (single rational coefficient) is less than the revised approach (weighted rational coefficient). The weighted rational coefficient was reduced through the replacement of highly impervious surfaces with more pervious surfaces. All other things being equal, a lower rational coefficient will result in lower peak flows. Note that final revised run (run 2) has a runoff coefficient that is less than the runoff coefficient associated with pre-developed condition. This scenario indicates that the proposed site in run 2 is able to absorb more runoff than the site was historically able to absorb.

If the soils on the site were classified as two (or more) hydrologic soil group types, impermeable surfaces constructed on the less pervious soils would yield a lower Rational Coefficient than if the impermeable surfaces were constructed on the more pervious of the soil types.

PART 3 – MIMIC PRE-DEVELOPMENT FREQUENCY AND DURATION OF EVENTS

Small storms are responsible for most annual urban runoff and groundwater recharge. LID techniques seek to intercept rainfall, reduce the extent of directly connected impervious surfaces, and slow down the rate of runoff. These techniques best mimic the pre-development frequency and duration of small storm events and are preferred.

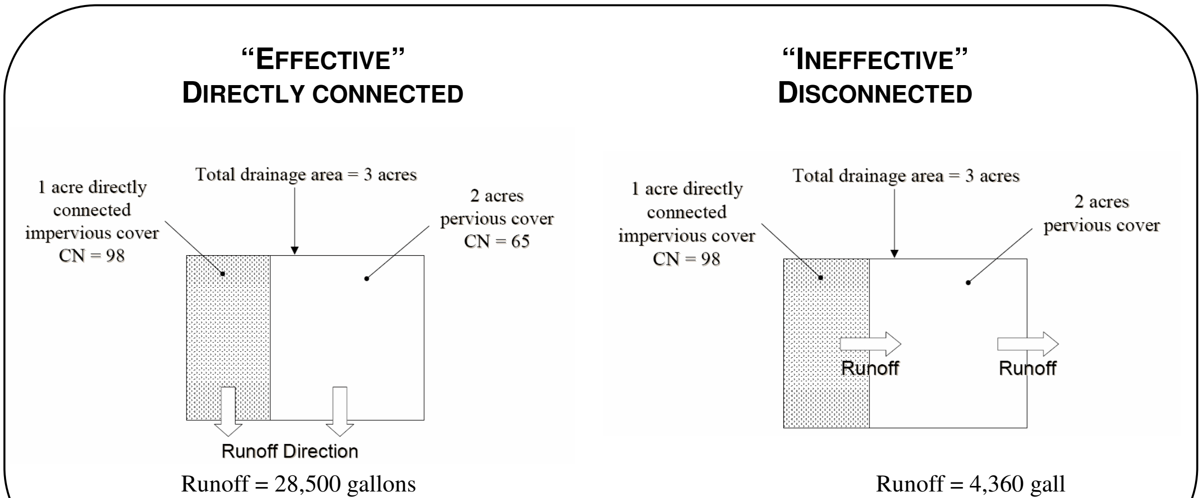
Section 6.3.2 discussed rainfall interception techniques and is not repeated here. This section includes recommendations to reduce the extent of effective impervious surface area and increase the time of concentration.

Reduce Directly Connected Impervious Areas (DCIA)

Studies have shown adverse biological impacts to surface waters in watersheds with effective impervious area (EIA) greater than 2-3% (Horner, 2007).

Effective impervious areas are areas such as rooftops, streets, sidewalks, and parking lots that drain directly to a stream or wetland system via pipes or by sheet flow. They are considered “effective” because the effectively drain the landscape.

Impervious areas that drain to landscapes, swales, parks and other impervious areas are considered “ineffective” because the water is allowed to infiltrate through the soil and into groundwater, without a direct connection to the stream of wetland. As show in the figure below, this decreases the runoff volume and increases the time of concentration.



(Obropta, Rutgers Cook College)

Reducing effective impervious area means to disconnect impervious surfaces from the drainage system so that runoff does not flow directly to streams. Disconnecting the stormwater system allows the watersheds' hydrologic cycle to respond in a manner that more closely reflects pre-disturbed conditions (though it does not restore such condition). DCIA reduction can occur as part of new development, redevelopment, or be part of a retrofit design. The level of benefit is determined by how well the practices minimize runoff in small to mid size storm events.

Maintain or Increase the Time of Concentration

Practices that increase the time it takes for runoff to travel across a site include:

Roughening the travel path surface (vegetation vs pavement or pipes)
Incorporating check dams and grade changes to allow interim ponding
Lengthening the flow path
Converting concentrated flow back into sheet flow
Disconnecting impervious areas

Maintaining or exceeding the existing time of concentration using the techniques discussed above will reduce peak flows during small storm events.